Utilization and Purification of the Mine Waters at the Marcel and 1 Maja Coal Mines in the Upper Silesian Coal Basin (Poland)

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Abstract
Major pollution of the two main polish rivers Vistula and Oder is caused by mine waters discharged from coal mines of the Upper Silesian Coal Basin (USCB). This problem has increased by deeper excavation and the development exploitation of coal mine. This paper presents the solution to problems in the neighbouring active Marcel and closed 1 Maja coal mines. Natural high salinity mine waters containing sulphates flow into the active Marcel Coal Mine. Mine waters in the closed 1 Maja Coal Mine are brines with a high content of barium and radium isotopes. Utilization and purification of these waters should be by the transfer of brines from the Marcel CM into the closed 1 Maja CM where the waters containing barium and isotopes of radium occur. This paper presents also the idea of the utilization of energy accumulated in natural mine waters after filling the old mine workings, gobs and cavities of the closed 1 Maja CM by mine waters. Geothermal energy could be used in the local network of communal central heating.

Key words: brines, utilization, purification, geothermal energy

Introduction

Groundwater with different chemical composition and origin, from fresh water to brines, flow into the mines of the Upper Silesian Coal Basin (Różkowski et al. 2004, Pluta 2005). The latter became a great problem in the coal mining operations and the environment of the Upper Silesia. In the fifties of the last century when it was identified that some inflowing brines were highly saline two methods of solving the problem were proposed: desalination and the hydrotechnical method enabling controlled discharge of mine waters into surface waters. Using these methods and later some different mining technologies did not solve in full the problem of the salinity of the water environment in Upper Silesia. Many coal mines are emanating highly saline waters, among them the ones located in the south-western part of the Upper Silesian Coal Basin, including the Marcel Coal Mine (CM).
In order to limit the impact of the discharged brines on the surface waters they are disposed worldwide by injecting them directly into deep formations. The Framework Water Directive *WFD/2000/60/EC* published on 23 October 2000 and the *Directive 2006/118/EC* by the EU Parliament and Council of 12 December 2006 on protecting groundwaters against pollution and worsening their quality recommend pumping brines into deep geological strata, storing high salinity waters in geological strata.
Taking into account the provisions of the Framework Water Directive that emphasise the need to eliminate polluting the surface waters by dumping waste water by the mining industry and that recommend disposing waste waters by directing to geological strata it was decided to direct the brines flowing into the mine workings of the Marcel CM to neighbouring formations.
This paper presents performance of the activities aimed at limiting the salinity of mine water from the Marcel CM by directing it into the old mine workings, gobs and cavities in the neighbouring, closed 1 Maja CM as well as a proposal to retrieve the geothermal heat from the water after flooding the colliery.

The hydrogeological conditions at the Marcel and 1 Maja coal mines

The Marcel and the closed 1 Maja coal mines are located in the south-west part of the Upper Silesian Coal Basin. The area is characterised by different geological structure and various hydrogeological conditions.

The hydrogeological conditions in the Carboniferous formations within the Marcel CM are connected with the occurrence of the coal deposits situated in two geological areas: Jejkowice trough and Chwałowice trough. These formations have different lithologic shaping, larger share of sandstone strata in the Chwałowice trough (Marklowice part of the mine) and larger share of non-permeable rocks or low permeable rocks (sandstones with low porosity) in the Jejkowice trough (original part of the mine) and different shaping of the overburden above the Miocene and Quaternary deposits. The coal-bearing formations of the Carboniferous in the Marklowice part are isolated from the waters of practically non-permeable strata of Miocene clays. Thus they are characterised mainly as the volume of free groundwater within the reservoirs originating from old hydrogeological cycles before the transgression in the Badenian. The waters in the original part of the Marcel CM are from the combined-sandstone-and-conglomerate series the outcrops of which are recharged by water from the Quaternary strata, often from groundwater renewable resources. Older fossil waters occur only in deeper levels of the Carboniferous formations.
The hydrogeological conditions at the closed 1 Maja CM are in contrast to those in the Marcel CM. They are of more uniform character as the mine extracted coal within the Chwałowice trough only in the area between the Orłów-Boguszowice thrust and the Michałkowice-Rybnik thrust. The coal-bearing formations are covered in this area by Quaternary and Miocene overburden. The considerable thickness of the latter and their practically non-permeable character ensures that there are no hydraulic connections between the Carboniferous and the overburden formations. Therefore in the area of the closed 1 Maja CM there are present fossil waters.
The Marcel CM is a neighbour to the closed 1 Maja CM and is connected to it by means of a drift at a depth of 610 m. The drift is inclined in the direction to the Marcel mine where it is located about 10 metres below the working at the 1 Maja mine (where it is located at a depth of 600 m).

The chemical composition of the waters proposed to be directed into gobs and cavities within the take of the 1 Maja CM

Brines flow into the west part of the Marcel CM (the original part), where the seams of Jaklowiec (Namurian) are extracted. In the water samples taken in the years 1995-1996 at the gate roads of longwall M-10a and longwall M-11, where the water inflow to 10-15 dm^3, concentrations of chloride ions from about 111 to about 129 g/dm^3 and of sulphate ions up to 315 mg/dm^3 were found. Since 2004 the waters of the inflow from the reservoir on the level 1000 m e.g. W-371/02 in the gobs of seam 703/1-2, have flowed into the opening workings of seam 707/2 (roads M-12 and M-13). Content of chloride ions in the waters from of seam 703/1-2 varies from about 70 to over 100 g/dm^3, whereas sulphate ions from about 1 to 2 g/dm^3. Mean concentration of chloride ions reaches 86 g/dm^3, and sulphate ions 1.5 g/dm^3. Their inflow caused increased quantities of salt dumps to the river Odra from the Marcel CM.
Thus it was proposed not to dump the brines into the surface waters but transfer them to the gobs and cavities of the closed, neighbouring 1 Maja CM.

The impact of the waters from the Marcel CM on the water at the 1 Maja CM

Reducing conditions exist in the waters of the 1 Maja CM. They are practically sulphate free and contain the barium ion in a concentration of up to 1630 mg/dm^3 and the isotopes of radium, among them ^{226}Ra, in a radioactive concentration of up to 80 Bq/dm^3 (Pluta et al., 2005). Mean concentration of chloride ions in the waters transferred from the „Marcel" mine to the old mine workings, gobs and cavities of the 1 Maja CM in 2006 amounted to about 48 g/dm^3, and sulphate ions about 1.1g/dm^3. The transfer of these brines containing sulphate ions to the waters of the 1 Maja CM which currently contain barium ions, will result in precipitation of barium sulphate as the waters from both the mines mix.
The transfer of the brines from the Marcel to the 1 Maja CM has a positive influence on the quality of its waters because it causes precipitation of barium and radioactive isotopes of radium which are the strongly hazardous substances in the water environment. The process takes place "at the source" at the place these flow pollutants into the mine are generated (Pluta et al., 2001; 2002).

The possibility to use geothermal energy

The area of the closed 1 Maja CM is situated within a positive anomaly of the geothermal field that is noted in the south-western part of the Upper Silesian Coal Basin, characterised by thermal flux values from 70 to 80 mW/m^2. That phenomenon causes the mine waters in favourable conditions to accumulate the natural heat (Karwasiecka 2001). The waters, after the flooding of the 1 Maja CM and inflow to the „Marcel" CM may be used as a source and medium of heat transfer (Bukowski 2002; Karwasiecka et al., 2004). Assuming that it will be possible to reach a rate of taking of 2 m^3/min and to cool it down by 15^oC translates into a thermal energy potential of 2 MW that may be used by means of a geothermal installation. In such conditions it will necessary to maintain a balance between the water supply using the water from the nearby areas and the waters stemming from draining the neighbouring Marcel CM and the value of flux of the thermal water taken to the surface. If the balance is not maintained a deficit of mass is possible as well as cooling down of the deposit. Geothermal investments based on usage of water sources located in closed mines are justified not only by the ecological considerations as these limit the emission of combustion products into the atmospheric air but also are justified economically as it is not necessary to drill deep wells and it possible to use the existing infrastructure of the closed mine.

Conclusions

The Marcel CM is connected with the abandoned 1 Maja mine. This connection was prepared to be used as an opening for draining the 1 Maja CM after it is flooded.

Into the workings located in the western part of the Marcel CM (the original part of the mine) flow the brines from the seams 703-707 at the level 1000 m. Since 2004 analyses of the waters have indicated a concentration of chloride ions reaching values of over 100 g/dm^3 and of sulphate ions up to 2.5 g/dm^3.

The old mine workings, gobs and cavities of the closed 1 Maja CM are drowned by the inflowing brines that contrast with the waters flowing into the western part of the Marcel CM. They do not contain sulphate ions but are enriched in substances particularly hazardous to the natural water environment: barium and radioactive isotopes of radium. The content of barium ions reaches up to 2.5 g/dm^3, as regards the radioactive isotopes the most radiotoxic isotope of radium ^{226}Ra reaches up to 80.0 Bq/dm^3.

It was proposed that the brines flowing into the „Marcel" CM should be disposed into the old mine workings, gobs and cavities in the Carboniferous formations of the closed 1 Maja CM. The solution gave measurable ecological and economic advantages. The disposal of the „Marcel" mine's brines into the gobs and old workings of the flooded 1 Maja CM (taking into account the future draining of waters from the 1 Maja CM and disposal into the surface waters after the mine has been abandoned) also causes elimination of pollutants: barium and radium ions which are particularly hazardous in the water environment. The precipitation the elements occurs on the spot, in the rock mass of the Carboniferous formations. Moreover after the 1 Maja CM has been flooded up to a depth of 610 m it is possible to use the geothermal heat contained in the mine water gathered in the mine. Geothermal energy could be used in the local network of communal central heating.

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References

Bukowski P, (2002) The water storage capacity of a carboniferous rock mass and its impact on the flooding process of mine, workings in the Upper Silesian Coal Basin Archives of Mining Sciences 47, 3: p 385-412

Karwasiecka M, (2001) Nowe wyniki badań gęstości powierzchniowego strumienia cieplnego Ziemi w obszarze Górnośląskiego Zagłębia Węglowego. W: Plewa S., red., „Rozpoznanie pola cieplnego Ziemi w obszarze Górnośląskiego Zagłębia Węglowego dla potrzeb górnictwa i ciepłownictwa". Studia Rozprawy Monografie 90. Instytut Gospodarki Surowcami Mineralnymi i Energią PAN. Kraków

Karwasiecka M, Wagner J, Kwarciński J., Bukowski P., Marcol A, (2004) Ocena potencjalnych zasobów energii cieplnej gromadzonej w wodach dołowych nieczynnej KWK „1 Maja". Materiały XXVII Sympozjum Geologia formacji węglonośnych Polski, 21-22 kwietnia 2004. Kraków.

Pluta I, Ślaski R, Jaszek D, (2001) Odwadnianie zatapianej kopalni „1 Maja" – Koncepcja uwzględniająca zagrożenie hydrochemiczne". W: Materiały Seminarium „Wody kopalń południowej części GZW. Ich zanieczyszczenie i sposoby oczyszczania". S II

Pluta I, Widuch T, Piotrowski Z, (2002) Odwadnianie zatapianej kopalni „1 Maja" – koncepcja uwzględniająca zagrożenie hydrochemiczne. W: Materiały Konferencji „Doświadczenia z likwidacji zakładów górniczych", Mysłowice: p113-116
Pluta I, (2005) Wody kopalń Górnośląskiego Zagłębia Węglowego –geneza, zanieczyszczenia i metody oczyszczania, Prace Naukowe GIG, nr 865: p169
Pluta I. et al., (2005) Koncepcja wykorzystania zrobów kopalni 1 Maja do ograniczenia zrzutu solanek kopalni Marcel: Dokumentacja GIG Katowice
Różkowski A (et al.), (2004) Środowisko hydrogeochemiczne karbonu produktywnego Górnośląskiego Zagłębia Węglowego. Wyd. UŚl, Katowice: p174.